(7) *Continuous constituent concentration*. For reference values, use a series of gas cylinders of known gas concentration or use a gas-division system that is known to be linear with a span gas. Gas cylinders, gas-division systems, and span gases that you use for reference values must meet the specifications of § 1065.750.

Table 1 of § 1065.307–Measurement systems that require linearity verifications

Measurement System	Quantity	Minimum verification frequency[a]	Linearity Criteria			
			$\lvert a_0 \rvert$[b]	a_1[c]	*SEE*[b]	r^2
Engine speed	f_n	Within 370 days before testing	≤0.05 % · f_{max}	0.98-1.02	≤2 % · f_{max}	≥0.990
Engine torque	T	Within 370 days before testing	≤1 % · T_{max}	0.98-1.02	≤2 % · T_{max}	≥0.990
Electrical work	W	Within 370 days before testing	≤1 % · W_{max}	0.98-1.02	≤2 % · W_{max}	≥0.990
Fuel flow rate	$\dot{m}$	Within 370 days before testing[d]	≤1 % · $\dot{m}_{max}$	0.98-1.02[e]	≤2 % · $\dot{m}_{max}$	≥0.990
Intake-air flow rate	$\dot{n}$	Within 370 days before testing[d]	≤1 % · $\dot{n}_{max}$	0.98-1.02[e]	≤2 % · $\dot{n}_{max}$	≥0.990
Dilution air flow rate	$\dot{n}$	Within 370 days before testing[d]	≤1 % · $\dot{n}_{max}$	0.98-1.02	≤2 % · $\dot{n}_{max}$	≥0.990
Diluted exhaust flow rate	$\dot{n}$	Within 370 days before testing[d]	≤1 % · $\dot{n}_{min}$	0.98-1.02	≤2 % · $\dot{n}_{max}$	≥0.990
Raw exhaust flow rate	$\dot{n}$	Within 185 days before testing[d]	≤1 % · $\dot{n}_{max}$	0.98-1.02[e]	≤2 % · $\dot{n}_{max}$	≥0.990
Batch sampler flow rates	$\dot{n}$	Within 370 days before testing[d]	≤1 % · $\dot{n}_{max}$	0.98-1.02	≤2 % · $\dot{n}_{max}$	≥0.990
Gas dividers	x	Within 370 days before testing	≤0.5 % · x_{max}	0.98-1.02	≤2 % · x_{max}	≥0.990
All gas analyzers	x	Within 35 days before testing	≤0.5 % · x_{max}	0.99-1.01	≤1 % · x_{max}	≥0.998
PM balance	m	Within 370 days before testing	≤1 % · m_{max}	0.99-1.01	≤1 % · m_{max}	≥0.998
Stand-alone pressures	p	Within 370 days before testing	≤1 % · p_{max}	0.99-1.01	≤1 % · p_{max}	≥0.998
Stand-alone temperatures	T	Within 370 days before testing	≤1 % · T_{max}	0.99-1.01	≤1 % · T_{max}	≥0.998

[a] Perform a linearity verification more frequently if the instrument manufacturer recommends it or based on good engineering judgment.

[b] "max" refers to the maximum value expected during a test—the maximum value used for the linearity verification.

[c] The specified ranges are inclusive. For example, a specified range of 0.98-1.02 for a_1 means $0.98 \leq a_1 \leq 1.02$.

[d] These linearity verifications are not required for systems that pass the flow-rate verification for diluted exhaust as described in § 1065.341 (the propane check) or for systems that agree within ±2 % based on a chemical balance of carbon or oxygen of the intake air, fuel, and exhaust.

[e] a_0 and a_1 for these quantities are required only if the actual value of the quantity is required, as opposed to a signal that is only linearly proportional to the actual value.

§ 1065.308 Continuous gas analyzer system-response and updating-recording verification.

(a) *Scope and frequency*. Perform this verification after installing or replacing a gas analyzer that you use for continuous sampling. Also perform this verification if you reconfigure your system in a way that would change system response. For example, perform this verification if you add a significant volume to the transfer lines by increasing their length or adding a filter; or if you change the frequency at which you sample and record gas-analyzer concentrations.

(b) *Measurement principles.* This test verifies that the updating and recording frequencies match the overall system response to a rapid change in the value of concentrations at the sample probe. Gas analyzer systems must be optimized such that their overall response to a rapid change in concentration is updated and recorded at an appropriate frequency to prevent loss of information.

(c) *System requirements.* To demonstrate acceptable updating and recording with respect to the system's overall response, use good engineering judgment to select one of the following criteria that your system must meet:

(1) The product of the mean rise time and the frequency at which the system records an updated concentration must be at least 5, and the product of the mean fall time and the frequency at which the system records an updated concentration must be at least 5. This criteria makes no assumption regarding the frequency content of changes in emission concentrations during emission testing; therefore, it is valid for any testing.

(2) The frequency at which the system records an updated concentration must be at least 5 Hz. This criteria assumes that the frequency content of significant changes in emission concentrations during emission testing do not exceed 1 Hz.

(3) You may use other criteria if we approve the criteria in advance.

(4) For PEMS, you do not have to meet this criteria if your PEMS meets the overall PEMS check in § 1065.920.

(d) *Procedure.* Use the following procedure to verify the response of a continuous gas analyzer system:

(1) *Instrument setup.* Follow the analyzer system manufacturer's start-up and operating instructions. Adjust the system as needed to optimize performance.

(2) *Equipment setup.* Using minimal gas transfer line lengths between all connections, connect a zero-air source to one inlet of a fast-acting 3-way valve (2 inlets, 1 outlet). Using a gas divider, equally blend an NO–CO–CO_2–C_3H_8–CH_4 (balance N_2) span gas with a span gas of NO_2. Connect the gas divider outlet to the other inlet of the 3-way valve. Connect the valve outlet to an overflow at the gas analyzer system's probe or to an overflow fitting between the probe and transfer line to all the analyzers being verified.

(3) *Data collection.* (i) Switch the valve to flow zero gas.

(ii) Allow for stabilization, accounting for transport delays and the slowest instrument's full response.

(iii) Start recording data at the frequency used during emission testing. Each recorded value must be a unique updated concentration measured by the analyzer; you may not use interpolation to increase the number of recorded values.

(iv) Switch the valve to flow the blended span gases.

(v) Allow for transport delays and the slowest instrument's full response.

(vi) Repeat the steps in paragraphs (d)(3)(i) through (v) of this section to record seven full cycles, ending with zero gas flowing to the analyzers.

(vii) Stop recording.

(e) *Performance evaluation.* (1) If you chose to demonstrate compliance with paragraph (c)(1) of this section, use the data from paragraph (d)(3) of this section to calculate the mean rise time, $T_{10\text{–}90}$, and mean fall time, $T_{90\text{–}10}$, for each of the analyzers. Multiply these times (in seconds) by their respective recording frequencies in Hertz (1/second). The value for each result must be at least 5. If the value is less than 5, increase the recording frequency or adjust the flows or design of the sampling system to increase the rise time and fall time as needed. You may also configure digital filters to increase rise and fall times.

(2) If a measurement system fails the criterion in paragraph (e)(1) of this section, ensure that signals from the system are updated and recorded at a frequency of at least 5 Hz.

(3) If a measurement system fails the criteria in paragraphs (e)(1) and (2) of this section, you may use the continuous analyzer system only if the deficiency does not adversely affect your

ability to show compliance with the applicable standards.

§ 1065.309 Continuous gas analyzer uniform response verification.

(a) *Scope and frequency.* If you use more than one continuous gas analyzer to quantify a gaseous constituent, you must perform this verification. For example, if you determine NMHC as the difference between continuous THC and CH_4 measurements, you must perform this verification on your NMHC measurement system. As another example if you determine NO_X as the sum of separate continuous measurements of NO and NO_2, you must perform this verification on your NO_X measurement system. Also, you must perform this verification if you use one continuous analyzer to apply an interference compensation algorithm to another continuous gas analyzer. Perform this verification after initial installation or major maintenance. Also perform this verification if you reconfigure your system in a way that would change system response. For example, perform this verification if you add a significant volume to the transfer lines by increasing their length or by adding a filter; or if you change the frequency at which you sample and record gas-analyzer concentrations.

(b) *Measurement principles.* This procedure verifies the time-alignment and uniform response of combined continuous gas measurements.

(c) *System requirements.* Demonstrate that combined continuous concentration measurements have a uniform rise and fall during a simultaneous to a step change in both concentrations. During a system response to a rapid change in multiple gas concentrations, demonstrate that the t_{50} times of all combined analyzers all occur at the same recorded second of data or between the same two recorded seconds of data.

(d) *Procedure.* Use the following procedure to verify the response of a continuous gas analyzer system:

(1) *Instrument setup.* Follow the analyzer system manufacturer's start-up and operating instructions. Adjust the system as needed to optimize performance.

(2) *Equipment setup.* Using minimal gas transfer line lengths between all connections, connect a zero-air source to the inlet of a 100 °C heated line. Connect the heated line outlet to one inlet of a 100 °C heated fast-acting 3-way valve (2 inlets, 1 outlet). Using a gas divider, equally blend an NO–CO–CO_2–C_3H_8–CH_4 (balance N_2) span gas with a span gas of NO_2 (balance N_2). Connect the gas divider outlet to the inlet of a 50 °C heated line. Connect the heated line outlet to the inlet of a 50 °C gas bubbler filled with distilled water. Connect the bubbler outlet to another heated line at 100 °C. Connect the outlet of the 100 °C line to the other inlet of the 3-way valve. Connect the valve outlet to an overflow at the gas analyzer system's probe or to an overflow fitting between the probe and transfer line to all the analyzers being verified.

(3) *Data collection.* (i) Switch the valve to flow zero gas.

(ii) Allow for stabilization, accounting for transport delays and the slowest instrument's full response.

(iii) Start recording data at the frequency used during emission testing.

(iv) Switch the valve to flow span gas.

(v) Allow for transport delays and the slowest instrument's full response.

(vi) Repeat the steps in paragraphs (d)(3)(i) through (v) of this section to record seven full cycles, ending with zero gas flowing to the analyzers.

(vii) Stop recording.

(e) *Performance evaluations.* Perform the following evaluations:

(1) *Uniform response evaluation.* (i) Calculate the mean rise time, t_{10-90}, mean fall time, t_{90-10} for each analyzer.

(ii) Determine the maximum mean rise and fall times for the slowest responding analyzer in each combination of continuous analyzer signals that you use to determine a single emission concentration.

(iii) If the maximum rise time or fall time is greater than one second, verify that all other gas analyzers combined with it have mean rise and fall times of at least 75% of that analyzer's response.

(iv) If any analyzer has shorter rise or fall times, disperse that signal so that it better matches the rise and fall times of the slowest signal with which